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TR 68-1

AD832237

TECHNICAL REPORT NO. 68-1

SOLION SEISMOMETER ENVIRONMENTAL TESTS

STATEMENT #2 UNCLASSIFIED

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GEOTECH

A TELEDYNE COMPANY

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Air Force Technical Applications Center
VELA Seismological Center
Washington, D. C.

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

20 April 1968

IDENTIFICATION

AFTAC Project No:	VELA T/7702
Project Title:	Operation of TFSO
ARPA Order No:	624
ARPA Program Code No:	
Name of Contractor:	Teledyne Industries Incorporated Geotech Division Garland, Texas
Date of Contract:	1 January 1967
Amount of Contract:	$1,090,300
Contract Number:	AF 33(657)-67-C-0091
Contract Expiration Date:	31 December 1967
Program Manager:	B. B. Leichliter, BR1-2561

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ILLUSTRATIONS

TABLES

ABSTRACT

Environmental tests were performed on a set of solion seismographs with emphasis on determination of noise produced by voltage variations, temperature variations, and pressure change at the seismometers. The seismometers, developed and built by the Defense Research Laboratory of the University of Texas, use solion pressure transducers and mercury inertial masses. A long-period and a short-period response characteristic is obtained from each single seismometer by means of separate sets of filters in each amplifier. We concluded that useful short-period magnifications of more than two million and useful long-period magnifications of approximately fifty thousand could be obtained in a controlled field environment.

SOLION SEISMOMETER ENVIRONMENTAL TESTS

1. INTRODUCTION

1.1 AUTHORITY

The work described in this report was performed by Geotech under Project VT/7702, Contract F 33657-67-C-0091. A copy of our approved test program is included in the appendix.

1.2 PURPOSE

The purpose of these tests was to study the effect of environment on the solion seismometers. The tests cover the areas of response to temperature, response to pressure, and response to voltage variations.

1.3 PREVIOUS WORK

Both the name solion (SOLution ION device) and the pioneering work came in the early 1950's from the U. S. Naval Ordnance Laboratory. Solions were then used in low-power signal processing applications but were soon superseded by solid-state devices in these applications. In the 1960's, the Defense Research Laboratory (DRL) of the University of Texas began to study solions for use as electromechanical transducers and through a U. S. Coast and Geodetic Survey Contract developed the seismometers tested in this program.

1.4 SCOPE

Defense Research Laboratory reports do not show that the effects of environment, especially temperature, have been studied in any detail.

Based on the reports reviewed and on discussion with DRL, we concluded that the effects of environment could come from pressure change, temperature change, and/or from power supply voltage variation. In order to control these conditions, the tests were performed in a test chamber in which the individual environments could be varied or held constant.

The testing was performed with both the horizontal and vertical seismometers in the same isolated pier-mounted sealed tank. Styrofoam cases were placed over the seismometers, and the remainder of the tank was filled with fiberglass insulation.

The program consisted of the following tests:

1. Power supply noise tests;
2. Bias supply noise tests;

3. Variation of temperature on installed seismometers and temperature convection tests;
4. Variation of pressure on installed seismometers;
5. Calibration and frequency responses;
6. System noise;
7. Vertical seismometer response to horizontal motion.

Section 2 contains a description of the seismographs and test facility used to acquire the data. Section 3 contains a discussion of the experimental results, graphs, and calibration data.

1.5 ACKNOWLEDGEMENTS

Appreciation is expressed to Mr. Robert Adair of Defense Research Laboratory for his help in familiarizing Geotech personnel with the operation of the solion seismometers.

2. DESCRIPTION OF SOLION SEISMOGRAPHS AND TEST FACILITY

2.1 SEISMOGRAPHS

The term solion is a contraction of SOLution ION device. There are several types, but the one of interest here is called the polarized cathode type. A solution of iodine and iodide ions is contained by diaphragms within a plastic housing. The ions being formed at the cathodes normally migrate to the anodes at a slow rate due to a bias applied between each set of electrodes. Movement of the diaphragms because of a pressure differential across the solion transducer causes the charge transport process to increase between one set of electrodes and to decrease between the other set. The two anodes are connected together, and a voltage proportional to pressure is obtained between the two cathodes. The differential arrangement of the electrodes is such that changes in applied bias voltage tend to be cancelled at the solion differential output. The addition of a liquid mass (mercury) outside one of the diaphragms to apply pressure completes the basic ingredients for the seismometer. It is necessary to house the solion seismometer in a sealed case to provide a quiet pressure reservoir for the exposed diaphragm of the solion transducer. A vertical seismometer (figure 1) and a horizontal seismometer (figure 2) developed and built by DRL were tested at Geotech. The primary objective of the test program was to study the effects of temperature, pressure, and power supply variation on the operation of the solion seismometers.

The amplifier used with the seismometers, also designed and built by DRL, contains a power supply, a load circuit into which the output of the solion is coupled which also provides bias for the solion, two operational amplifiers, and filters to provide simultaneous long-period and short-period outputs. A front panel switch allows setting overall gain at times 25, 50, or 100. With either seismometer connected to the amplifier, adequate magnifications can be obtained using a Helicorder or Sanborn recorder to record the output of the amplifier.

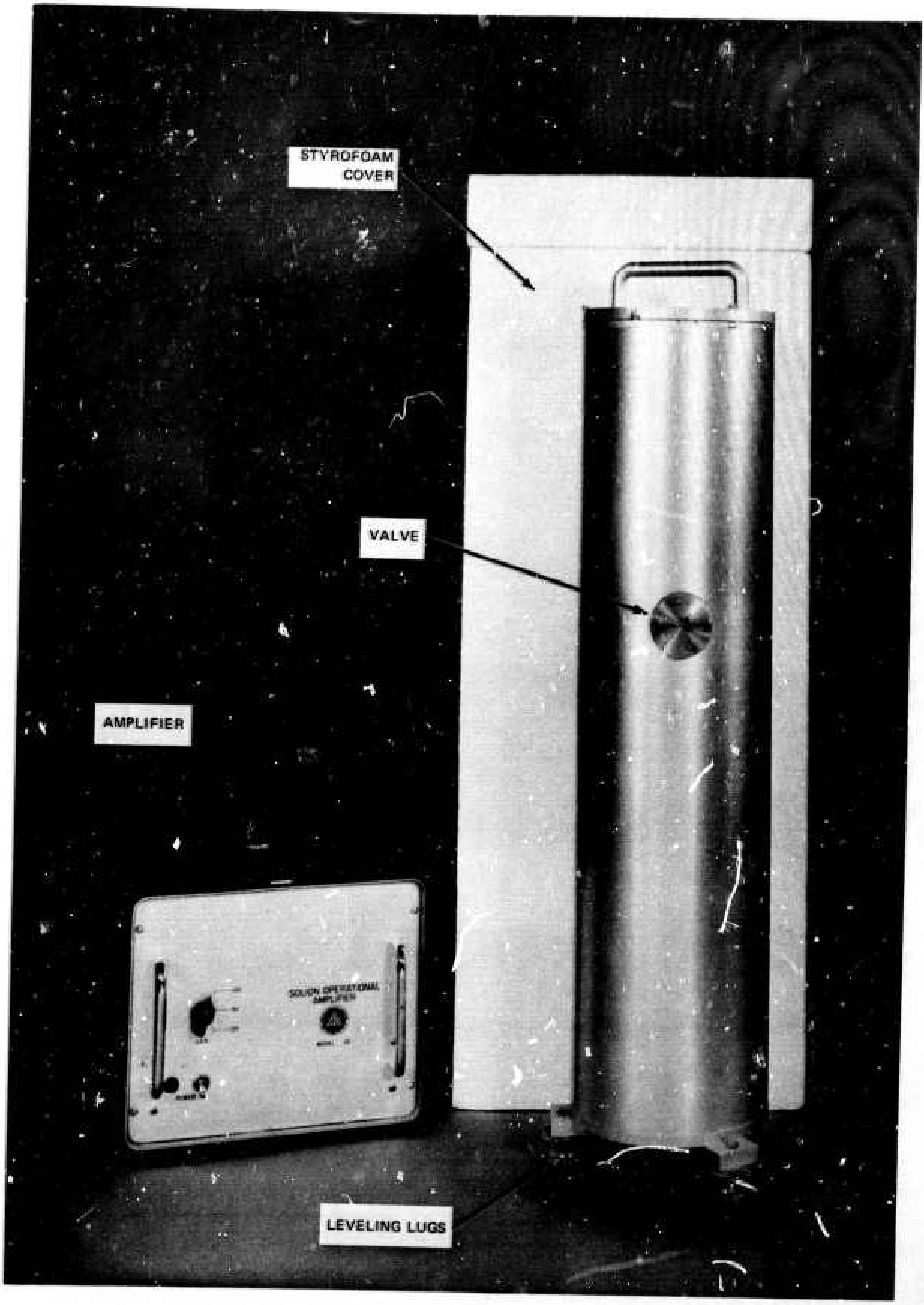


Figure 1. Vertical solion seismometer and amplifier

G 3915

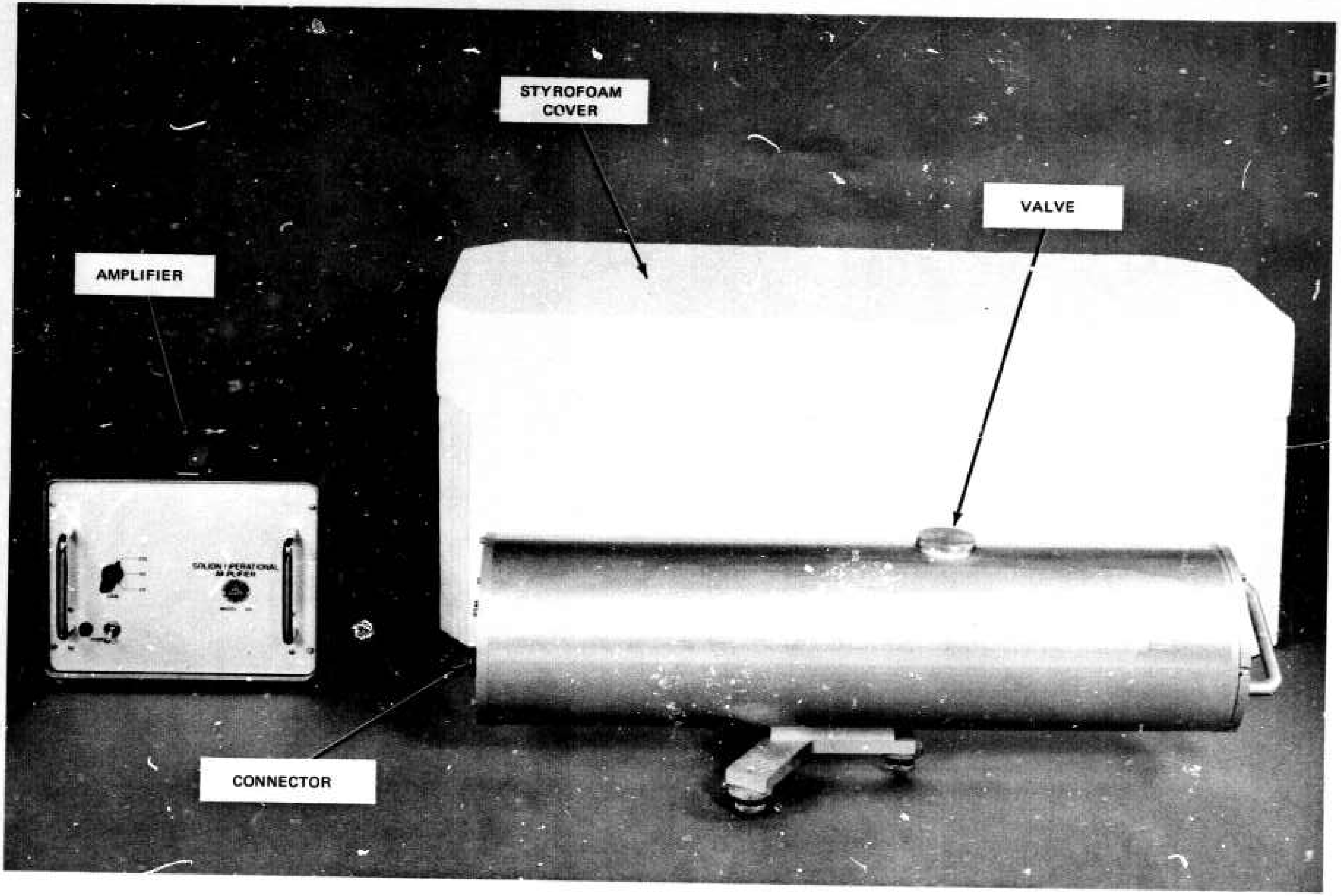


Figure 2. Horizontal solion seismometer and amplifier

G 3916

No unusual difficulty was encountered in setting up and operating the seismographs except that excess mercury or mercury vapor in the cases had acted on the soldered connections at the output plugs of both seismometers. The mercury had dissolved the solder and the leads to the plugs were found loose. They were resoldered and potted to prevent recurrence.

2.2 TEST FACILITY

The facilities of the Geotech environmental test laboratory were used in the solion system evaluation. A standard steel sealable tank vault set on Austin Chalk was used to house the solion vertical and horizontal seismometers. Heaters were placed near the seismometers and in the vault interior, so that the temperature could be varied.

Rectangular covers of styrofoam insulation were made to enclose the seismometers and separate them from the large vault interior. The remaining vault area was filled with formed pieces of fiberglass insulation. A general schematic of the test instrumentation is shown in figure 3.

A manometer and a diaphragm gauge were used to monitor vault pressure. Thermistor bridges and a thermocouple were used to monitor the vault temperature variations.

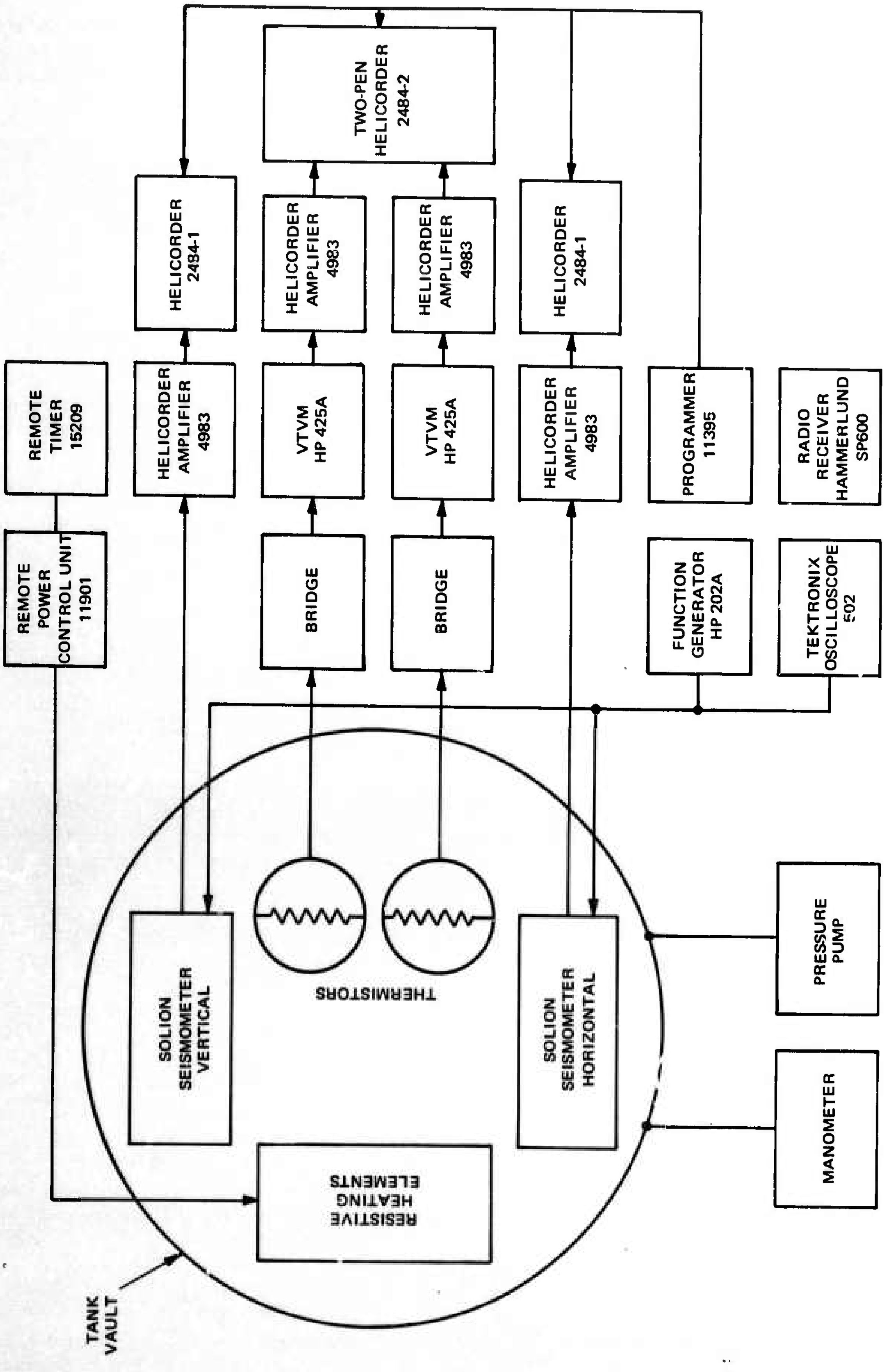
3. TEST PROCEDURE AND RESULTS

3.1 POWER SUPPLY VARIATION

The ±15-volt dc power supply in the solion amplifier was monitored with a Fluke 803B dc differential voltmeter and a Hewlett-Packard 425A microvolt-ammeter. The amplified voltage variations were recorded on a Helicorder at a sensitivity of 2.8 millivolts per millimeter. The maximum normal voltage change observed during a 36-hour interval was 20 millivolts. Larger changes were obtained (up to 100 millivolts) by loading the line at a point near the amplifier power input. With the amplifier dummy loaded at the input these larger changes in voltage produced transient disturbances in both long-period and short-period outputs of the amplifier. For the random change of up to 20 millivolts that normally is observed in the power supply voltage, no significant correlation with amplifier output noise was noted.

3.2 BIAS VOLTAGE VARIATION

The 0.5-volt bias across one side of the solion transducer was monitored by the same equipment used to record voltage variation of the power supply. All signals picked up by the seismometer produce bias voltage fluctuations. The ratio of amplifier output to bias voltage for a 0.05 cps calibration signal is approximately 1.1 volts output per millivolt bias change with the amplifier on X25 gain. With the seismometer mass blocked, however, there is little or no correlation between the bias fluctuations and noise at the amplifier outputs. Bias variations of up to 1 millivolt were recorded with the seismometer blocked while a noise



G 3917

Figure 3. Test instrumentation

level of approximately 25 millivolts was being recorded from the long-period output of the amplifier and 12 millivolts from the short-period output, with the amplifier set at maximum gain (X100). Therefore, while response of the seismometers to signals produced changes in bias, normally occurring changes in bias voltage had no observable effect on the amplifier output.

3.3 TEMPERATURE TESTS

3.3.1 Temperature Stabilization

Two 25-watt lamps connected in series were installed just inside the top cover of the vault. Ac power was connected through shielded leads from a variable voltage transformer, Geotech Model 11901 remote power control unit. Thermistors were placed inside the vertical seismometer's styrofoam cover, one at the bottom and one at the top. Bridges were connected to the thermistor leads and the imbalance was recorded on a Helicorder from the output of a Hewlett-Packard 425A microvolt-ammeter.

In order to obtain a zero temperature reference, a time switch was connected between the output of the microvolt-ammeter and the Helicorder to interrupt the circuit, periodically. Figures 4 and 5 give the details of the test arrangement.

Prior to activating the 25-watt lamps, the temperature inside the vertical seismometer styrofoam cover was 70 degrees Fahrenheit at the bottom and 71 degrees at the top. After 7 days with the lamps activated with 100 volts the temperature was 71.0 degrees Fahrenheit at the bottom and 72.5 degrees at the top. System magnification remained stable during this test, and there was no dc drift with heat applied at the top of the vault.

A 40-watt heating element, placed at the bottom of the vertical seismometer's styrofoam cover, was used to produce more rapid heating than could be obtained with the two 25-watt lamps. With the 40-watt heater, a temperature rise of 10 degrees Fahrenheit was produced in less than an hour. At this point, the seismometer became completely inoperative (figure 6), apparently because of solion imbalance that saturated the first operational amplifier. The seismograph became operative after the temperature change decreased. These results are summarized in table 1.

During periods of rapid heating or cooling of the seismometer, the average value of the differential voltage across the solion transducer changes from its normally low value (less than 2 millivolts) to relatively large values (20 millivolts or more) at a rate sufficient to produce excessive drift in the long-period output in spite of capacitive coupling of the two operational amplifiers in the solion amplifier.

During periods of cooling (or whenever the seismometer is warmer than its surroundings) large spikes and oscillations appear on the long-period seismogram (figure 7), even if cooling is not sufficiently rapid to cause excessive drift.

Because of apparent correlation between bias voltage and large changes in magnification of the vertical seismograph, additional tests were run in which the magnification and bias voltages were more closely monitored on both seismographs.

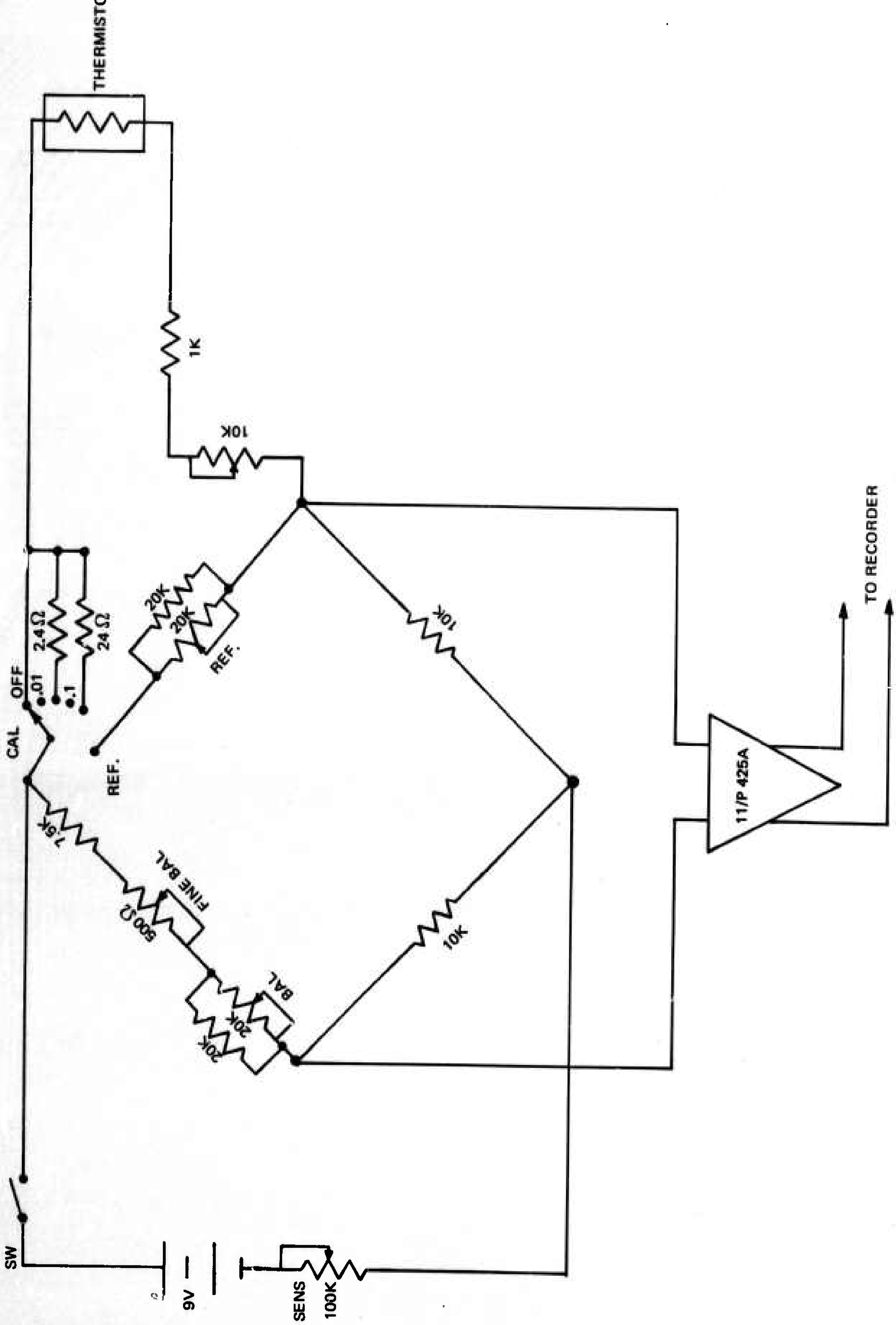


Figure 4. Thermistor bridge

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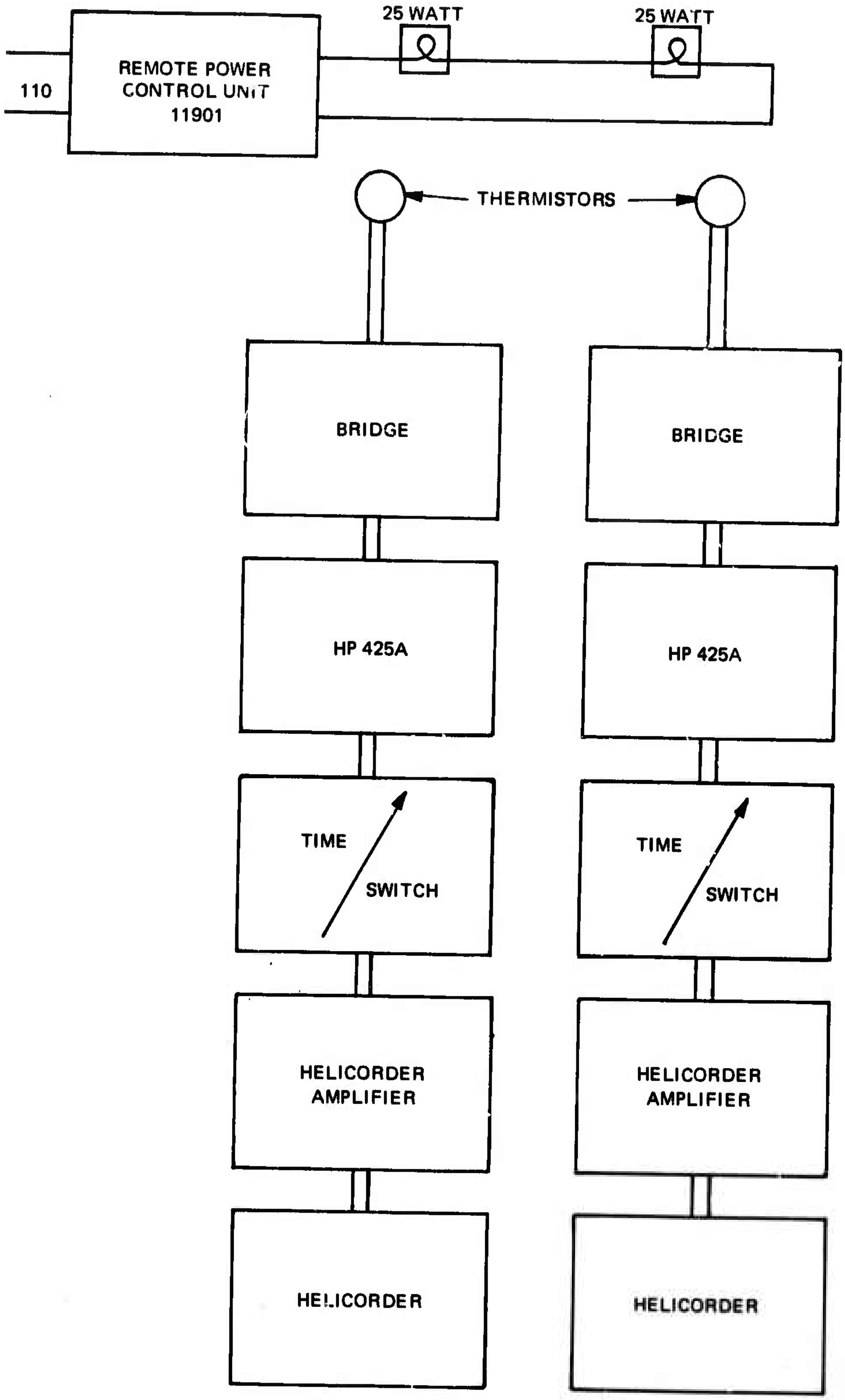

Figure 5. Diagram of temperature test equipment

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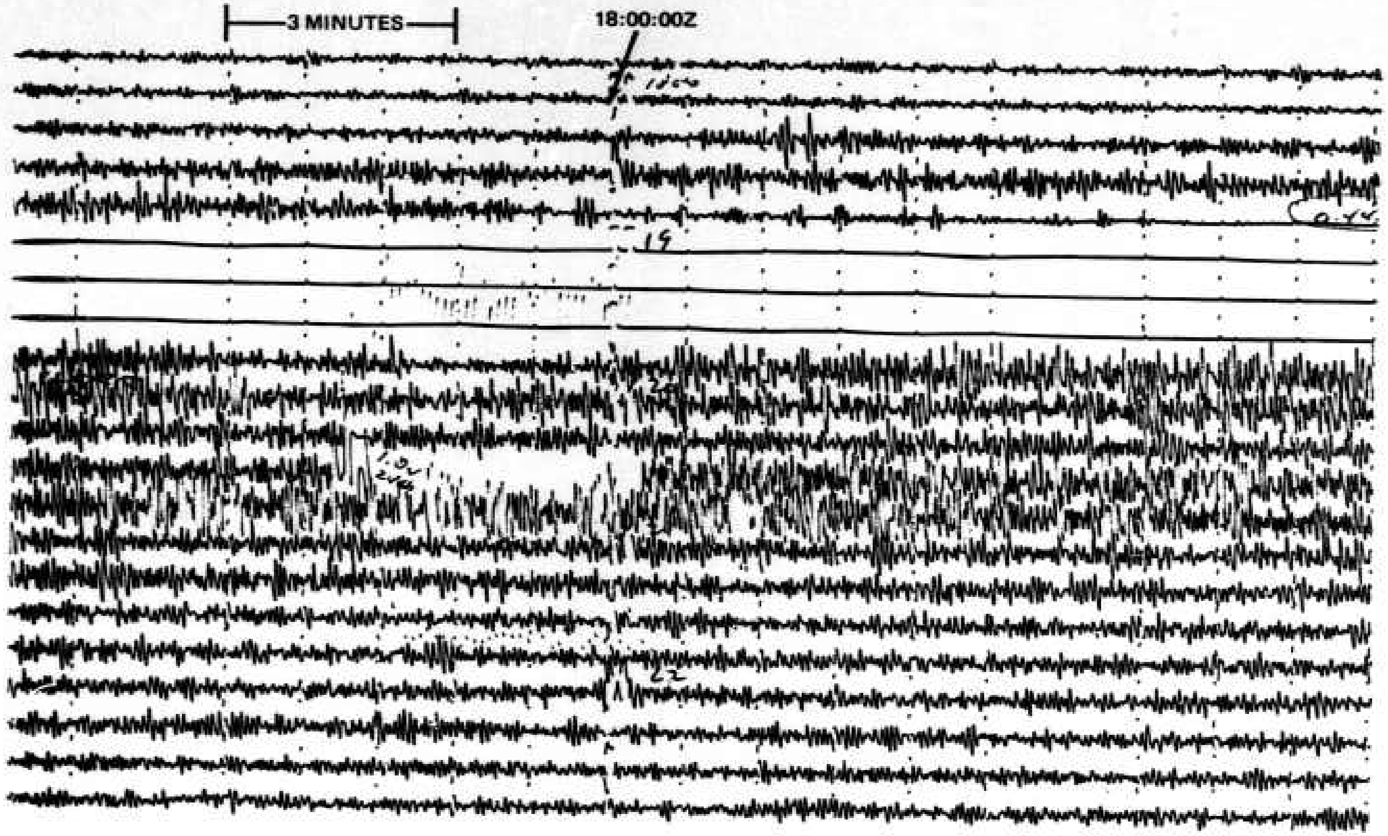

15 DEC 67
RUN 349

Figure 6. Solion short-period vertical seismogram showing increase in magnification and temporary period of inoperation resulting from rapid increase in temperature

Table 1. Magnification and bias variations of the vertical solion seismograph due to variation of temperature

Date	Time	Temp (°F[1])	SP Mag	LP Mag	Bias (v)	Condition
15 Dec 67	1521	72	66.6K	--	0.50	
	1756	72	--	--	0.50	Heat applied
	1845	82	--	--	0.445	Inoperative; heat reduced
	1940	83	--	--	0.45	Operative with increased gain on SP output and excessive drift on LP output
	2030	85	170K	23.2K	0.45	
	2234	85	111K	18.0K	0.49	
16 Dec 67	1517	87	70.2K	--	0.5	
	1800	88	67.5K	16.4K	0.5	
	2240	87.5	94.5K	--	0.5	
17 Dec 67	1730	87.5	96.0K	14.0K	0.5	
18 Dec 67	1440	87.5	83.5K	15.0K	0.5	
	1505	87.5	92.6K	16.6K	0.5	
	1622	87.5	--	--	0.5	Heat removed
	2138	77	--	19.4K	0.515	Large dc offset, drift spiking on LP output
19 Dec 67	1620	70	68.5K	15.6K	0.505	

[1]Temperature measured at top of styrofoam case

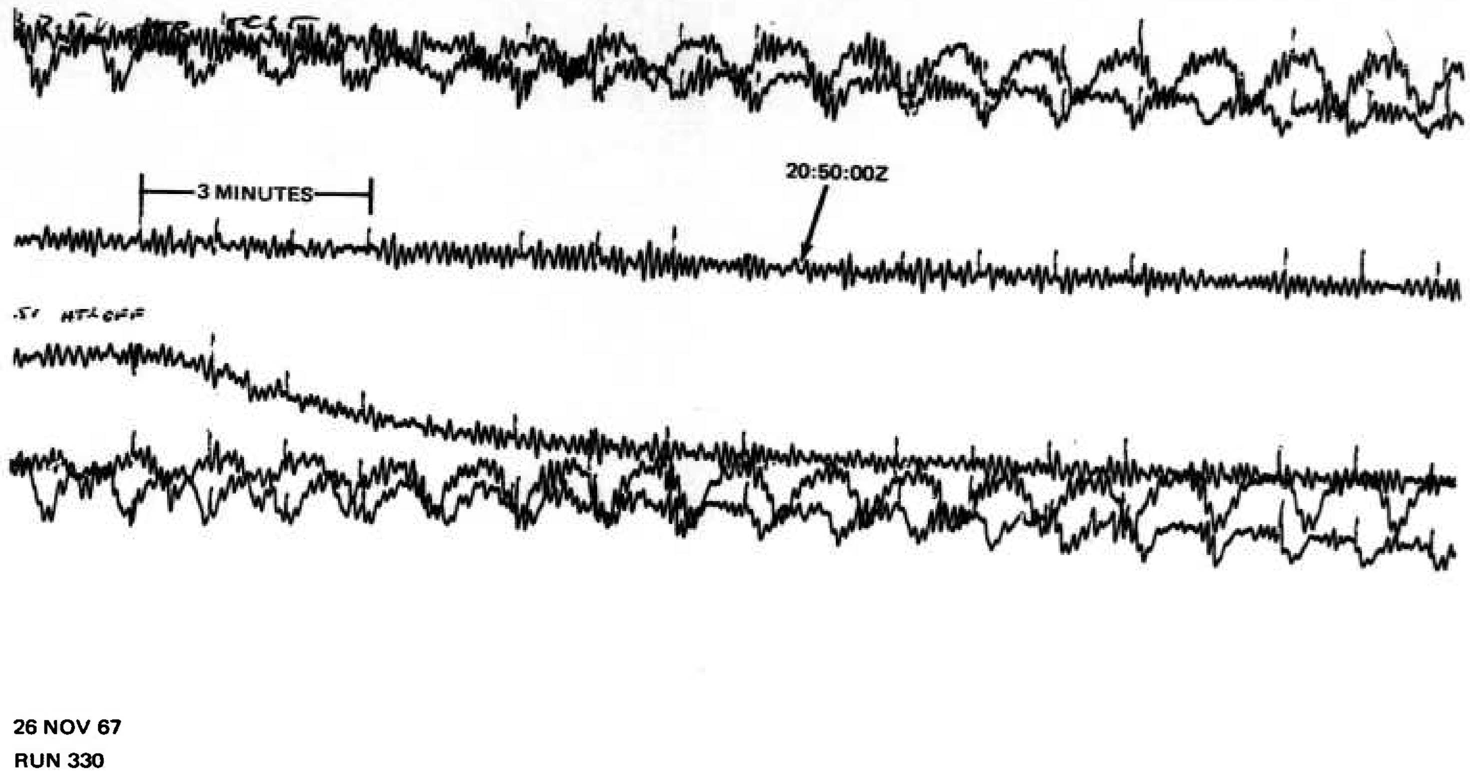

Figure 7. Solion long-period vertical seismogram showing drift and 1-minute oscillations due to rapid cooling of the seismometer

Both bias voltages for the solions in each seismometer were periodically recorded and the seismometers were calibrated at regular intervals. Heat was applied externally to the seismometer covers within the tank vault by one 100-watt and two 75-watt lamps. For the data shown in table 2, temperature was monitored near the top of the vertical seismometer within the styrofoam cover and at the top of the horizontal seismometer within its cover.

3.3.2 Temperature Convection Tests

Heating-cooling cycles of several different periods were produced by turning the vault heaters on and off at various intervals. At periods of 30 minutes to 3 hours and for ambient temperature changes in the vault of 2 to 8 degrees Fahrenheit, the two following general effects were observed on the long-period vertical seismogram: (1) The recording trace drifted in one direction during heating and in the opposite direction during cooling; the drift correlated with a change in the average value of the solion differential output from zero volts to values of as high as 20 millivolts. (2) During the periods of cooling, a regular, low-level oscillation with a period of approximately 1 minute occurred. These 1-minute oscillations occurred only during the last part of the cooling portions and the first part of the heating portions of the temperature cycles, and required approximately 1 hour to build up to a maximum amplitude. Neither the drift nor the 1-minute oscillations that disturbed the long-period seismogram were observable on the short-period recordings. The temperature changes at the horizontal seismometer were usually insufficient to produce these effects although the oscillations and drift have been observed on the horizontal long-period recordings during periods of temperature stabilization. Several temperature cycles were run with the mass of the vertical seismometer blocked by closing the valve in the mercury pipe and the 1-minute oscillations still appeared, indicating that the oscillations are produced by the solion transducer rather than by the mechanical portion of the seismometer or by air convection currents in the seismometer case. The drift in the solion transducer differential output voltage and in the long-period output, due to temperature changes, was present also with the seismometer mass blocked.

3.4 PRESSURE TESTS

Pressure changes of several periods and amplitudes were produced in the sealed tank vault by means of a sinusoidal pump. The pressure changes were monitored by a manometer and a pressure transducer. The response of the seismographs to the pressure changes is shown in table 3. It is doubtful that the response of the horizontal seismograph to the changes in pressure is due only to the action of pressure on the seismometer because stresses induced in the tank can cause tilting of the pier. It is likely that the response of the vertical seismograph represents more truly the direct effect of pressure on either seismometer.

3.5 CALIBRATION AND FREQUENCY RESPONSES

In order to have a basis for determination of magnification during the tests, the data on "equivalent earth motion per microampere of current into electromagnetic calibrator" given in table 3 of the Operation and Maintenance Manual for the Solion Universal Seismometer, DRL Tech. Memorandum CGS-1198-66-1, was

Table 2. Magnification and bias variations of the vertical and horizontal solion seismographs due to variation of temperature

Time	Temp (°F)		Vertical				Horizontal			
			Magnification		Bias		Magnification		Bias	
	Vert	Horiz	1.0 cps	0.05 cps	TP1-2	TP2-3	1.0 cps	0.05 cps	TP1-2	TP2-3
09:30	71	70	67K	550	0.510	0.510	90K	658	0.500	0.505
10:15	72	70.5	72K	550	0.518	0.520	86K	625	0.500	0.505
11:40	72.5	70.5	72K	575	0.515	0.520	99K	757	0.500	0.510
12:40	79.5	71	108K	612	0.505	0.525	108K	757	0.500	0.510
13:40	82	72	135K	688	0.492	0.525	108K	757	0.505	0.510
14:40	83	73	144K	725	0.492	0.525	108K	790	0.505	0.512
15:40	78.5	74	99K	625	0.510	0.520	108K	757	0.503	0.510
16:40	74.5	72	90K	612	0.520	0.515	104K	757	0.503	0.510

Table 3. Response of the solion seismographs to pressure change at several periods

Period (seconds)	Pressure		Equivalent ground motion on LP vertical		Equivalent ground motion on LP horizontal	
	Inches of H_2O	Millibars	Microns	Microns / millibar	Microns	Microns / millibar
13	1.40	3.49	0.50	0.14	1.4	0.40
13	1.82	4.53	0.75	0.17	1.3	0.29
20	1.40	3.49	0.49	0.14	1.6	0.46
23	1.82	4.53	0.82	0.18	2.2	0.49
24	1.82	4.53	0.99	0.22	2.5	0.55
26	1.24	3.09	0.89	0.29	2.4	0.78
36	1.82	4.53	1.65	0.36	8.2	1.8

used in the calibration of the seismographs. We also checked the values given for the vertical seismograph on the shake table and obtained values that agreed with those reported in the manual. In addition, relative frequency responses (figures 8, 9, and 10) were measured for both seismometers on shake tables and using the electromagnetic calibrators built into the seismometers (figures 11 and 12).

The sensitivity of the solion vertical seismometer (No. 3), amplified by the Solion Operational Amplifier, Model 101, at a gain of 25, was found to be approximately 8.3 volts per micron at 1.0 cps and 0.052 volt per micron at 0.05 cps. The corresponding sensitivity of the horizontal seismometer-amplifier combination was 8.1 volts per micron at 1.0 cps and 0.059 volt per micron at 0.05 cps.

3.6 SYSTEM NOISE

System noise level was measured with the vertical seismometer mass blocked by closing the valve in the mercury pipe. Under stable temperature conditions and with stable line voltage, the long-period system noise was less than 75 millimicrons equivalent ground motion at 20-seconds period. This corresponds to less than 1.0 millimeter noise at a magnification of 13.3K. The short-period system noise was a maximum of 0.36 millimicron or 1.0 millimeter at a magnification of 2.78 million.

3.7 SOLION VERTICAL SEISMOMETER RESPONSE TO HORIZONTAL MOTION

A cross-axis check of the solion vertical seismometer was run on the horizontal shake table in the frequency range 0.7-3.3 cps. It was found that the vertical response to horizontal motion was less than 0.6 percent.

4. EXAMPLES OF TYPICAL RECORDINGS OBTAINED DURING TESTING OF THE SOLION SEISMOGRAPHS

4.1 DAY-TO-DAY ACTIVITY

Figures 13, 14, and 15 show the normal day-to-day microseismic background activity at the Garland facility. The short-period horizontal seismograph was not recorded. The records start at about 6:00 p.m., CST, and are relatively quiet through the night until about 6:00 a.m., CST, as the morning activity picks up. The large excursions on the long-period records show the effects of trains switching cars into a nearby facility. The operating magnifications of the long-period seismographs were 6.2K and 8K at 0.05 cps and that of the short-period seismograph was 135K at 1 cps.

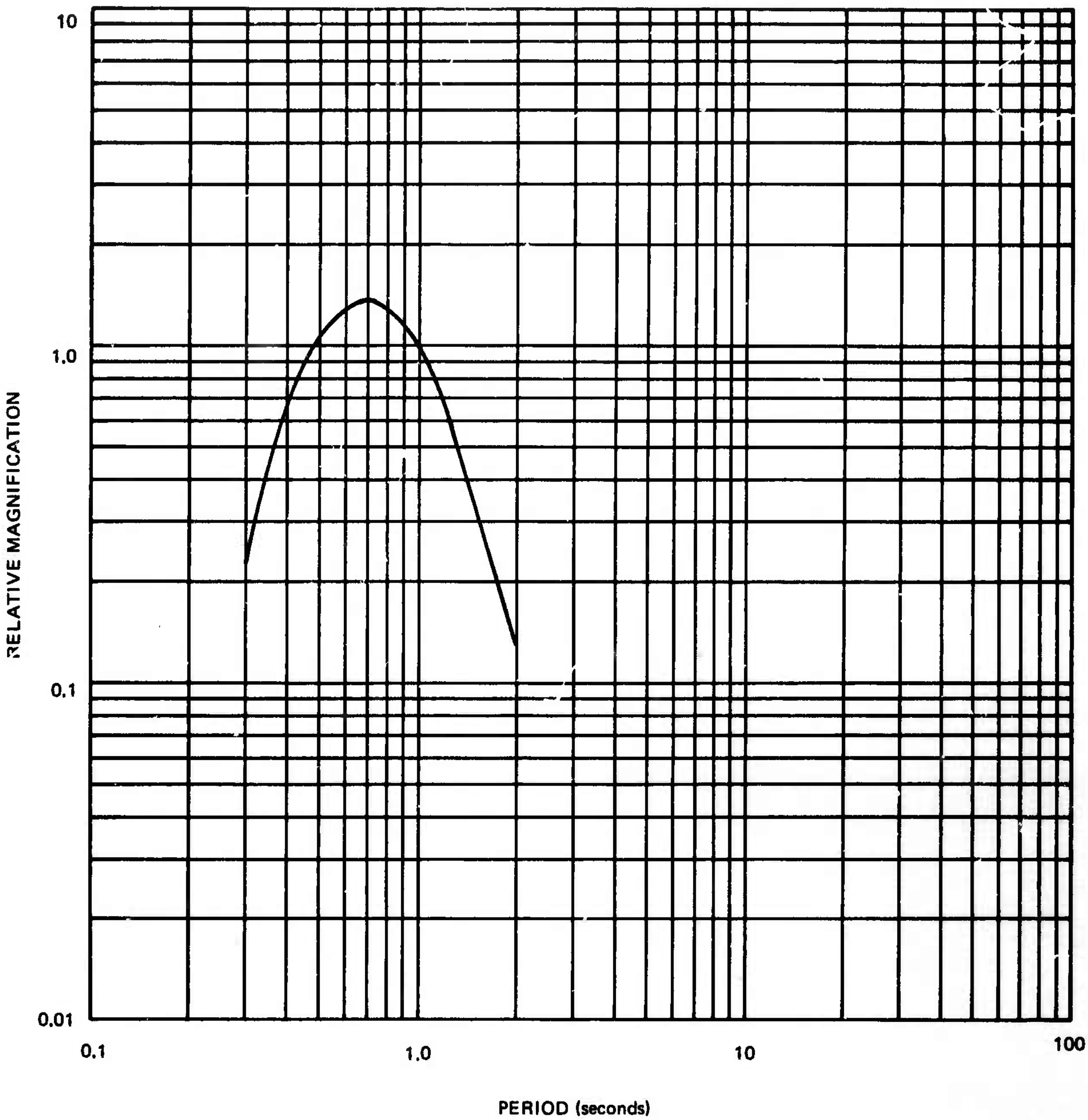

Figure 8. Response of the vertical solion short-period seismograph on the vertical shake table

G 3920

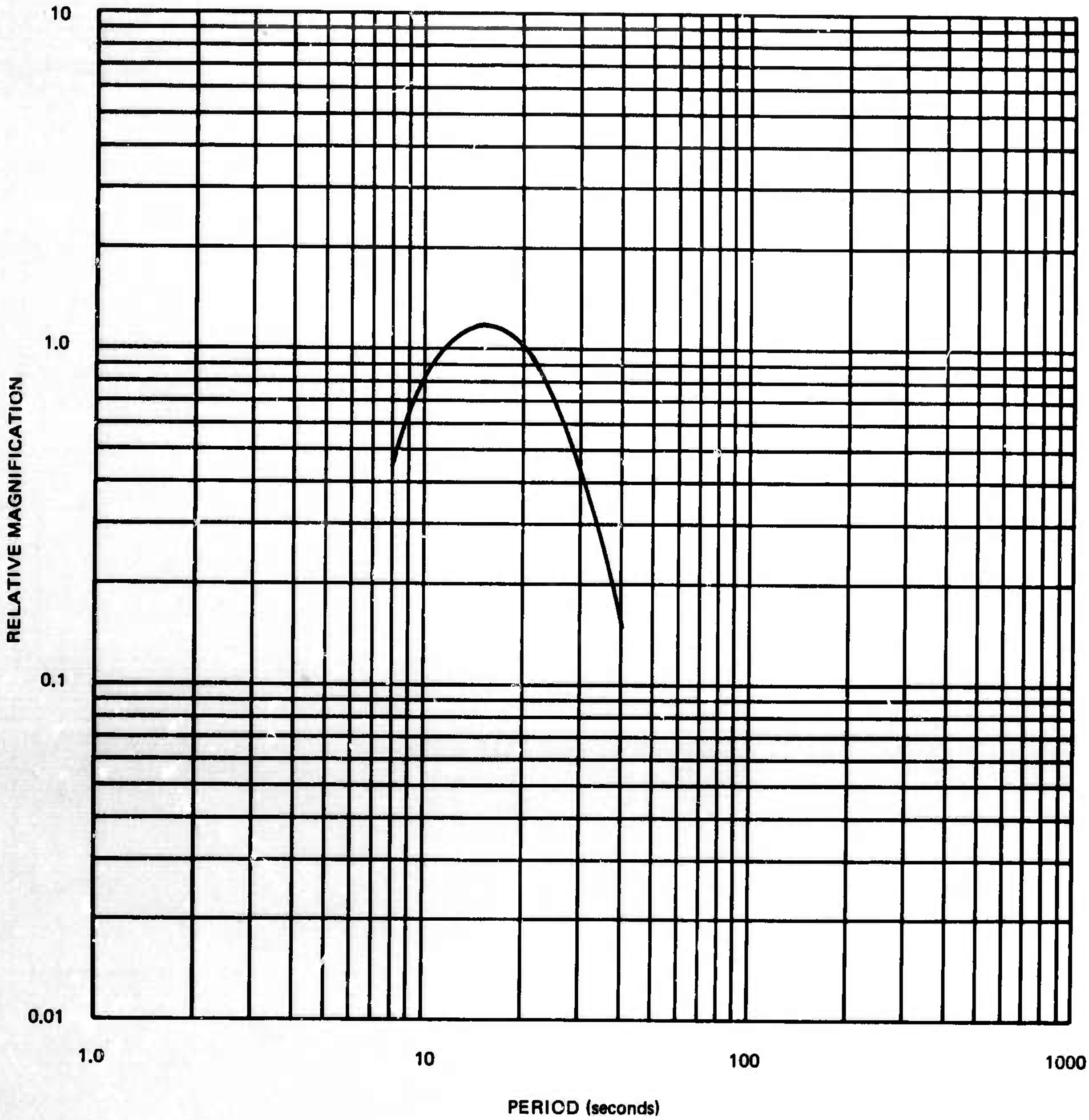

Figure 9. Response of the vertical solion long-period seismograph on the vertical shake table

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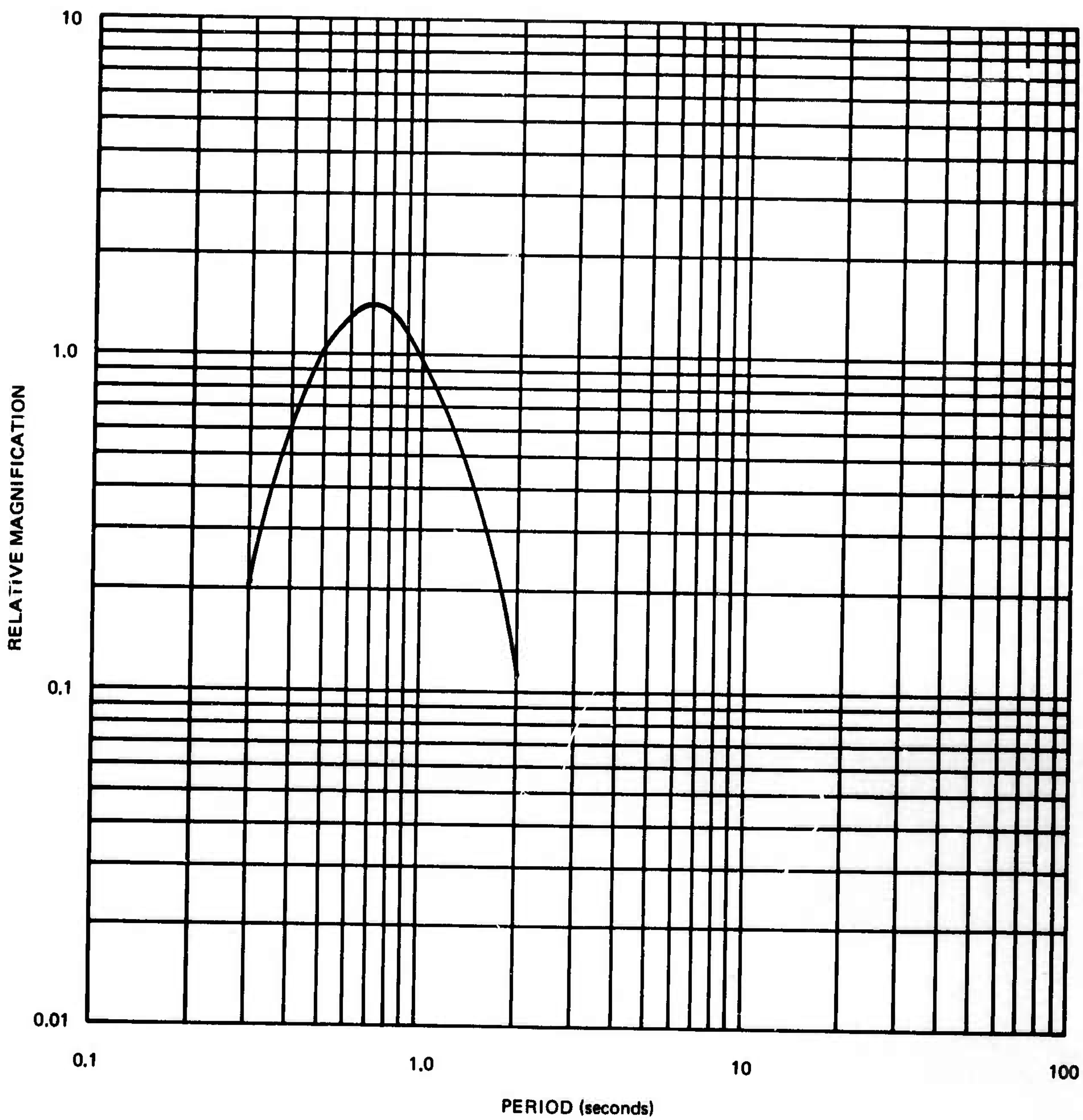

Figure 10. Response of the horizontal solion short-period seismograph on the horizontal shake table

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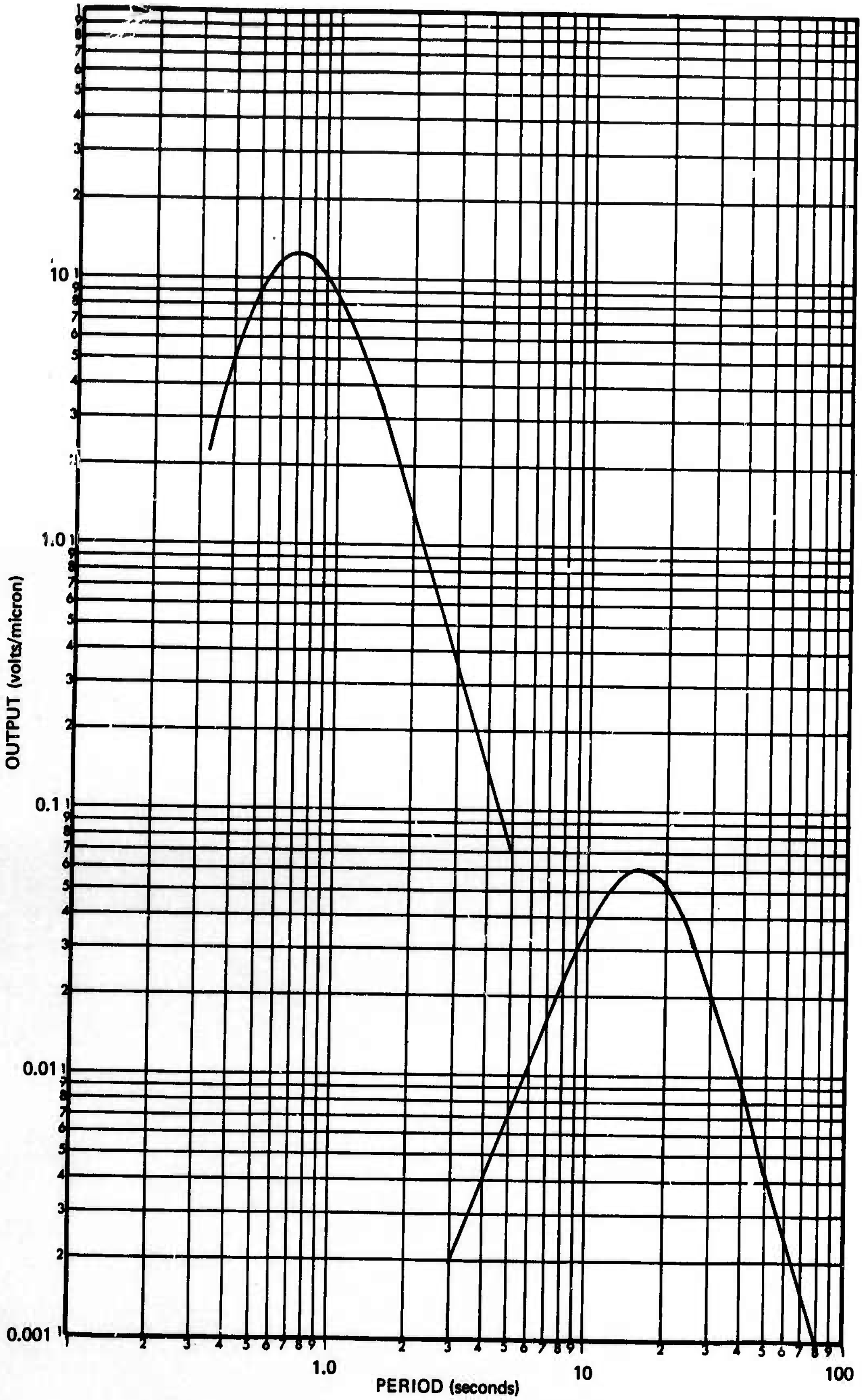

Figure 11. Vertical solion seismograph response measured with electro-magnetic calibrator

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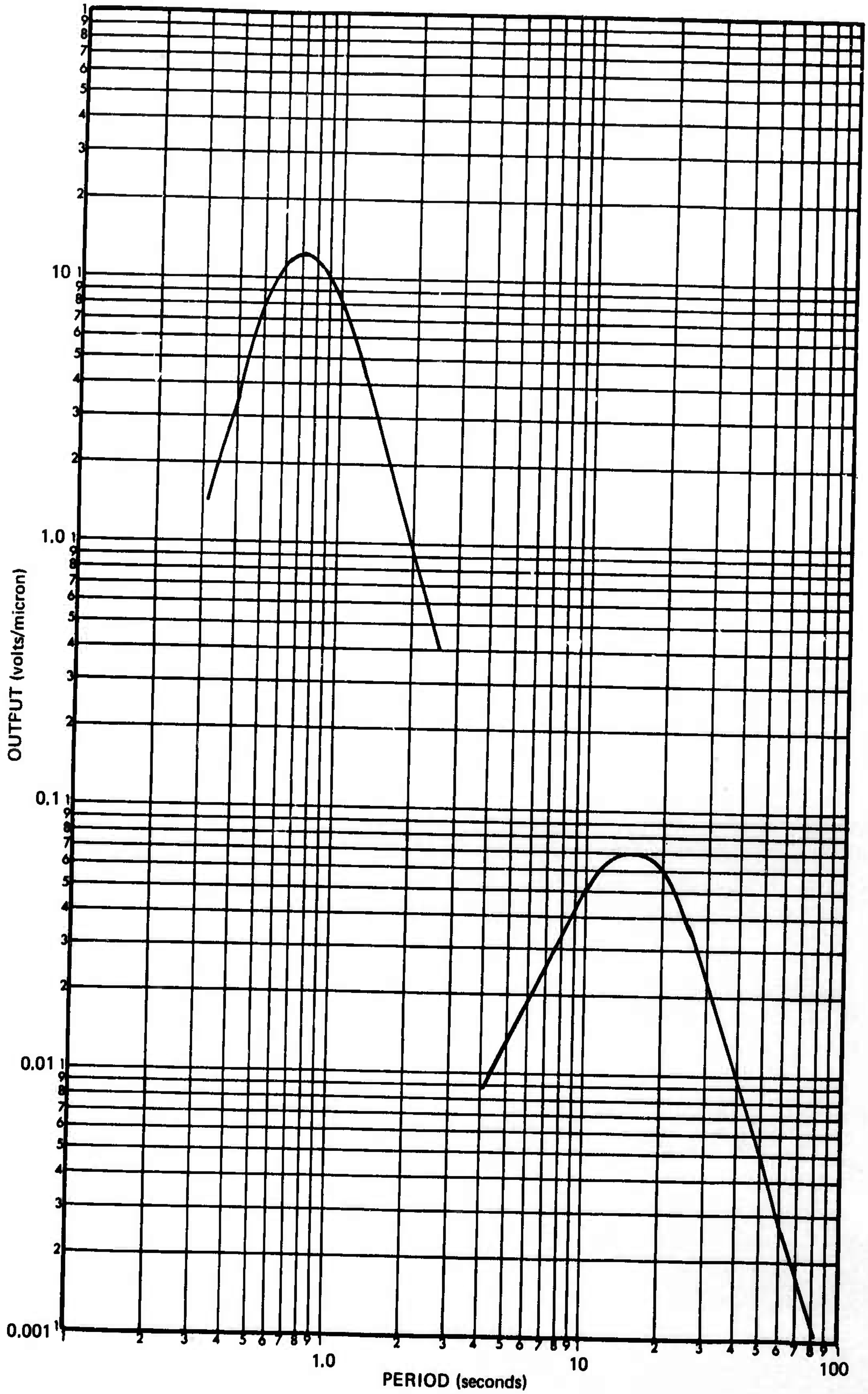

Figure 12. Horizontal solion seismograph response measured with electromagnetic calibrator

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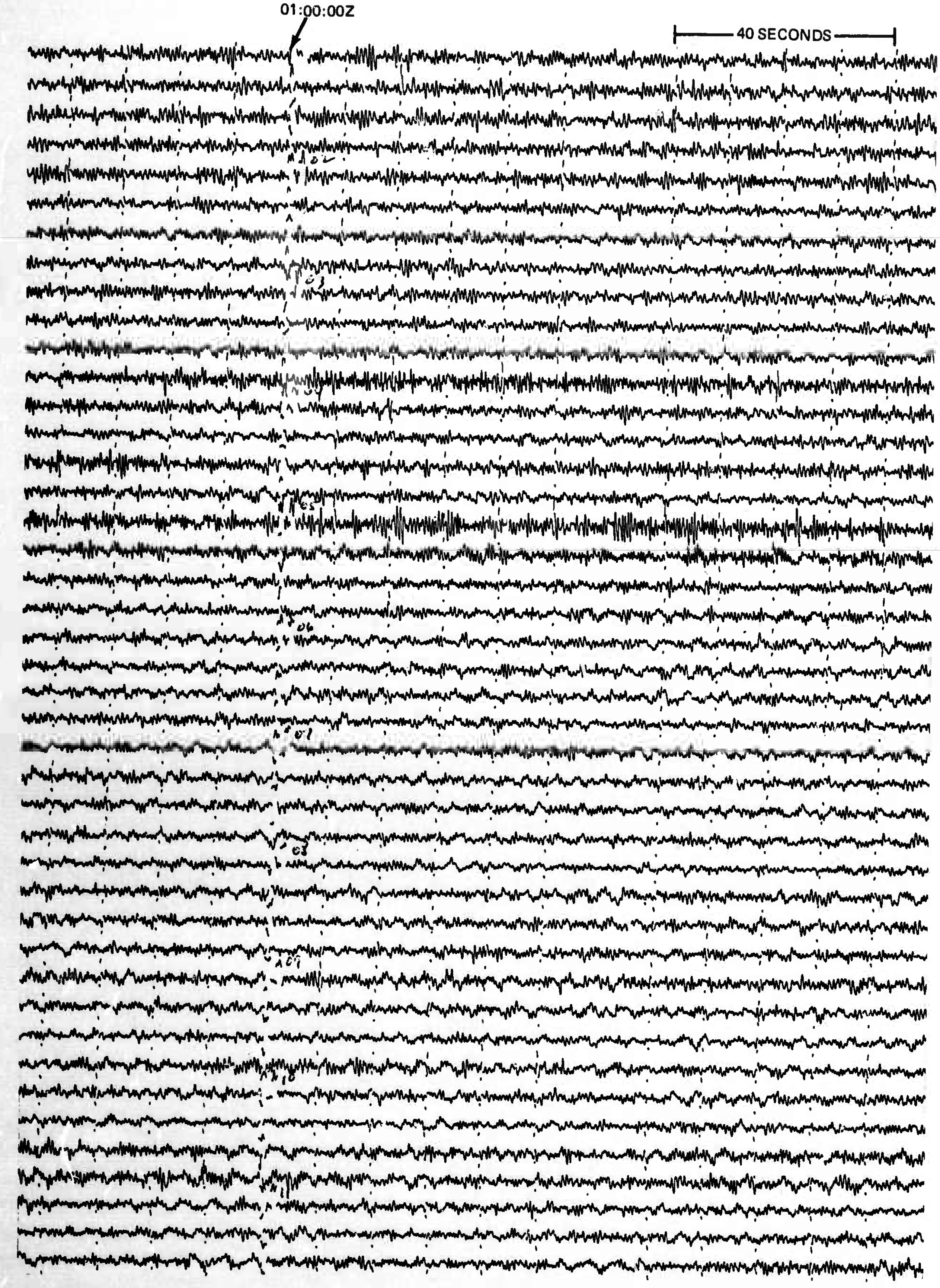


Figure 13, Typical short-period vertical seismogram
(Magnification at 1.0 cps, 135K)

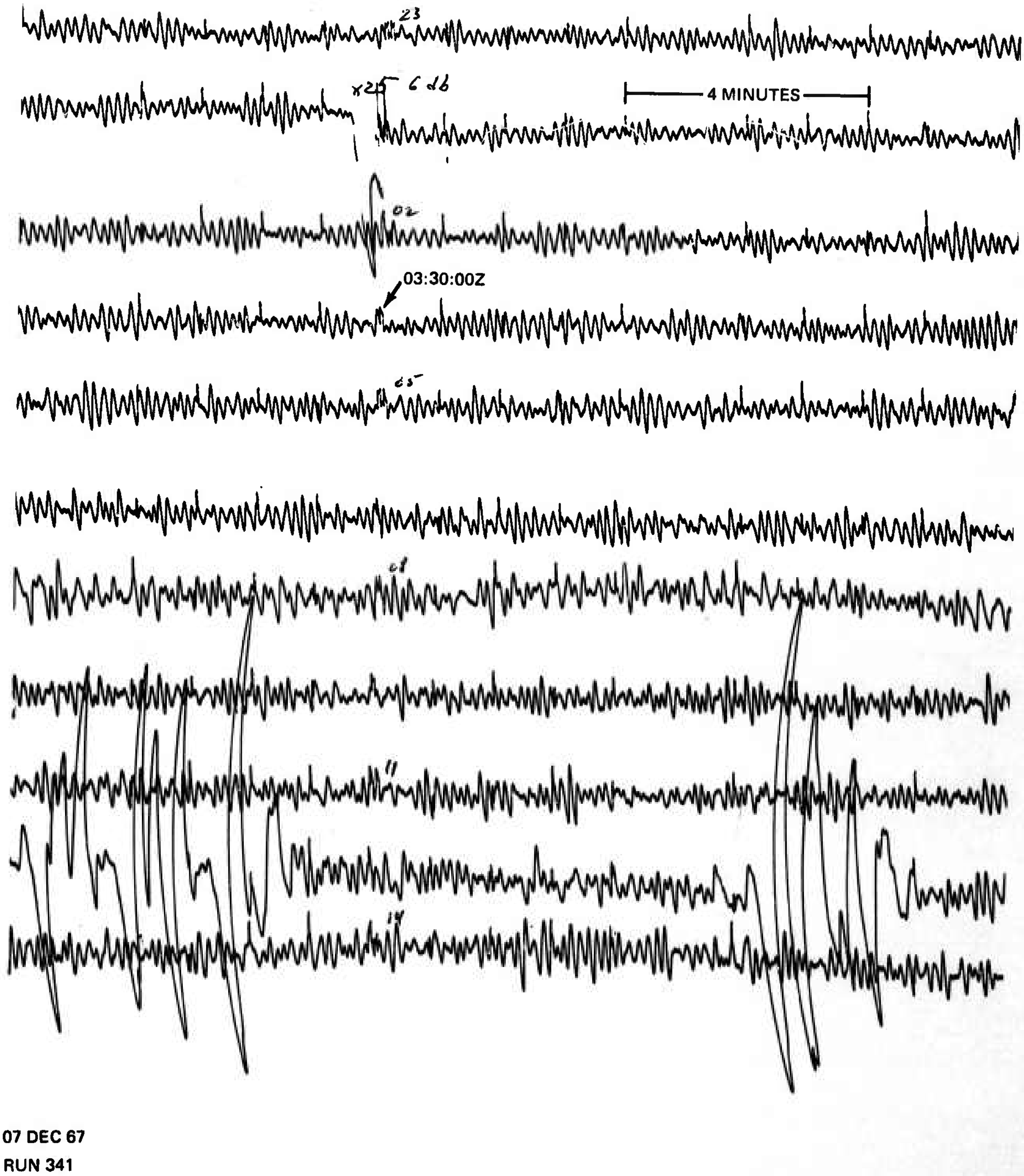


Figure 14. Typical long-period vertical seismogram (Magnification at 0.04 cps, 8K)

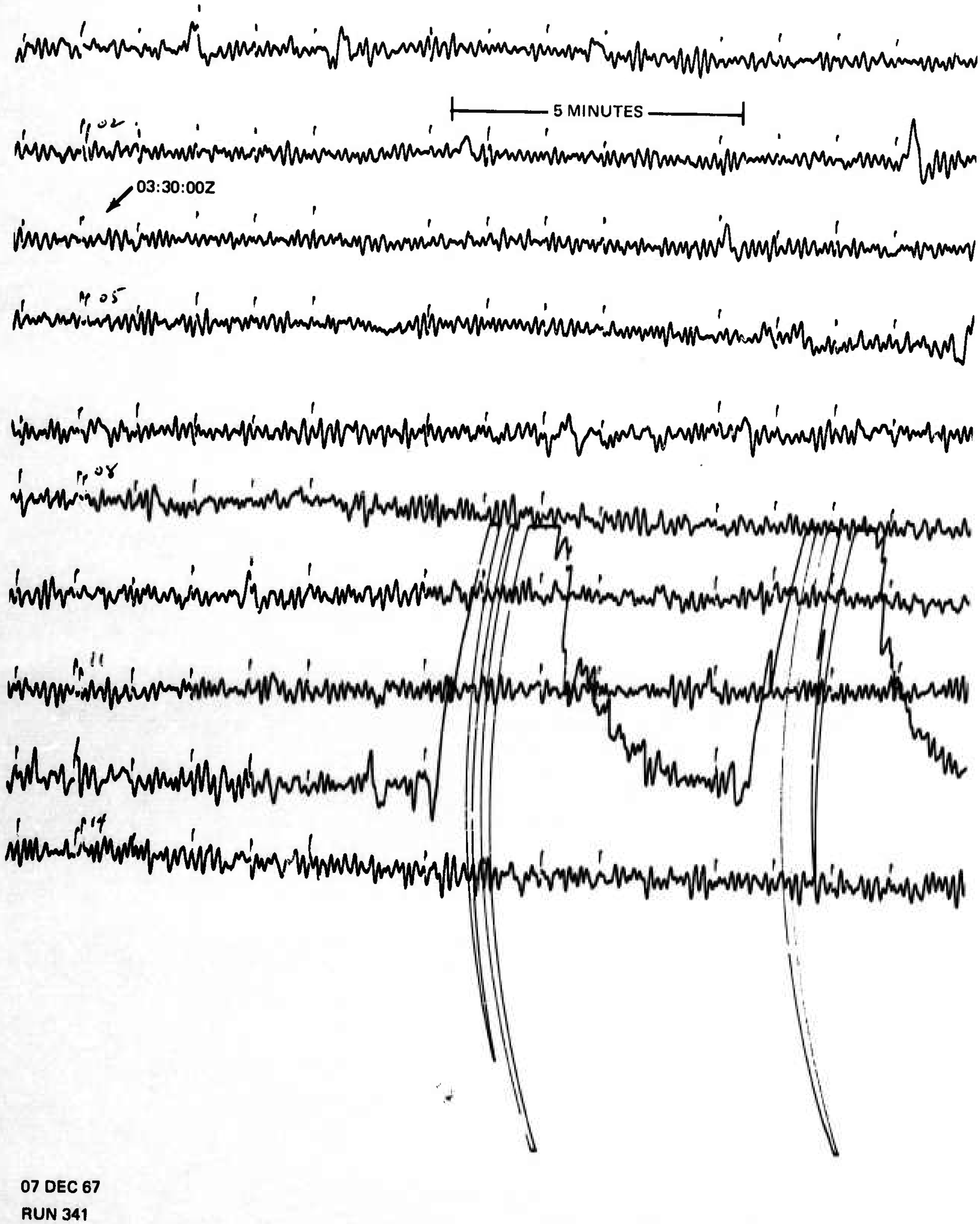


Figure 15. Typical long-period horizontal seismogram (Magnification at 0.04 cps, 6.2K)

4.2 RECORDING OF RAYLEIGH WAVE TRAIN FROM THE TONGA ISLANDS

The solion vertical long-period seismogram of a Rayleigh wave train from the Tonga Islands and the Southern Methodist University (SMU) world-wide vertical long-period seismogram of the same event are shown in figure 16. The maximum trace displacement of each seismogram indicates the same surface wave magnitude (5.3). The noise and spikes appearing on the solion trace with a period of about 66 seconds are the result of the seismometer cooling during a temperature test. Note that the polarity of the solion seismograph is reversed.

4.3 RECORDING OF SHORT-PERIOD P WAVE FROM A COLORADO EARTHQUAKE

The solion short-period vertical seismograph shows a similar response to that of the SMU world-wide short-period seismograph (figure 17). The first arrival is Pn followed approximately 40 seconds later by Pg.

5. CONCLUSIONS

The solion seismometers were found to be easily portable and relatively free from installation and operational difficulties if installed in a vault protected from diurnal temperature change.

Ambient temperature change produces several undesirable effects that are related to the rate of change of the seismometer temperature. The differential output voltage of the solion transducer apparently varies as the derivative of the temperature of the seismometer producing drift in the long-period output that is proportional approximately to the second derivative of the seismometer temperature (due to a single stage of capacitive coupling between the input of the amplifier and the long-period output). As the differential output voltage of the solion departs from a low value its gain increases, with more change in gain occurring for the short-period output than for the long-period output. In addition, if the temperature of the seismometer is decreasing, noise in the form of regular oscillations of about 1-minute period appears in the long-period output. The threshold temperature change below which these effects would not be observed is estimated to be approximately 2 degrees Fahrenheit per hour increasing, or 1/2 degree per hour decreasing temperature at the seismometer.

We concluded that power supply voltage variations and consequent bias voltage change do not appreciably increase the noise level of the solion seismograph under conditions of operation with a reasonably stable line voltage supply. Pulses appearing on the seismogram at infrequent intervals were correlated in some cases with the starting of motors on the same line; therefore, anything causing large voltage drops on the line voltage supply should be avoided, and use of a regulated voltage supply is recommended if stable line voltage is not available.

Pressure tests indicated that the sensitivity of the seismometer to pressure change is approximately 0.14 to 0.36 micron equivalent ground motion per millibar over the period range of 13 to 36 seconds, and that the sensitivity is

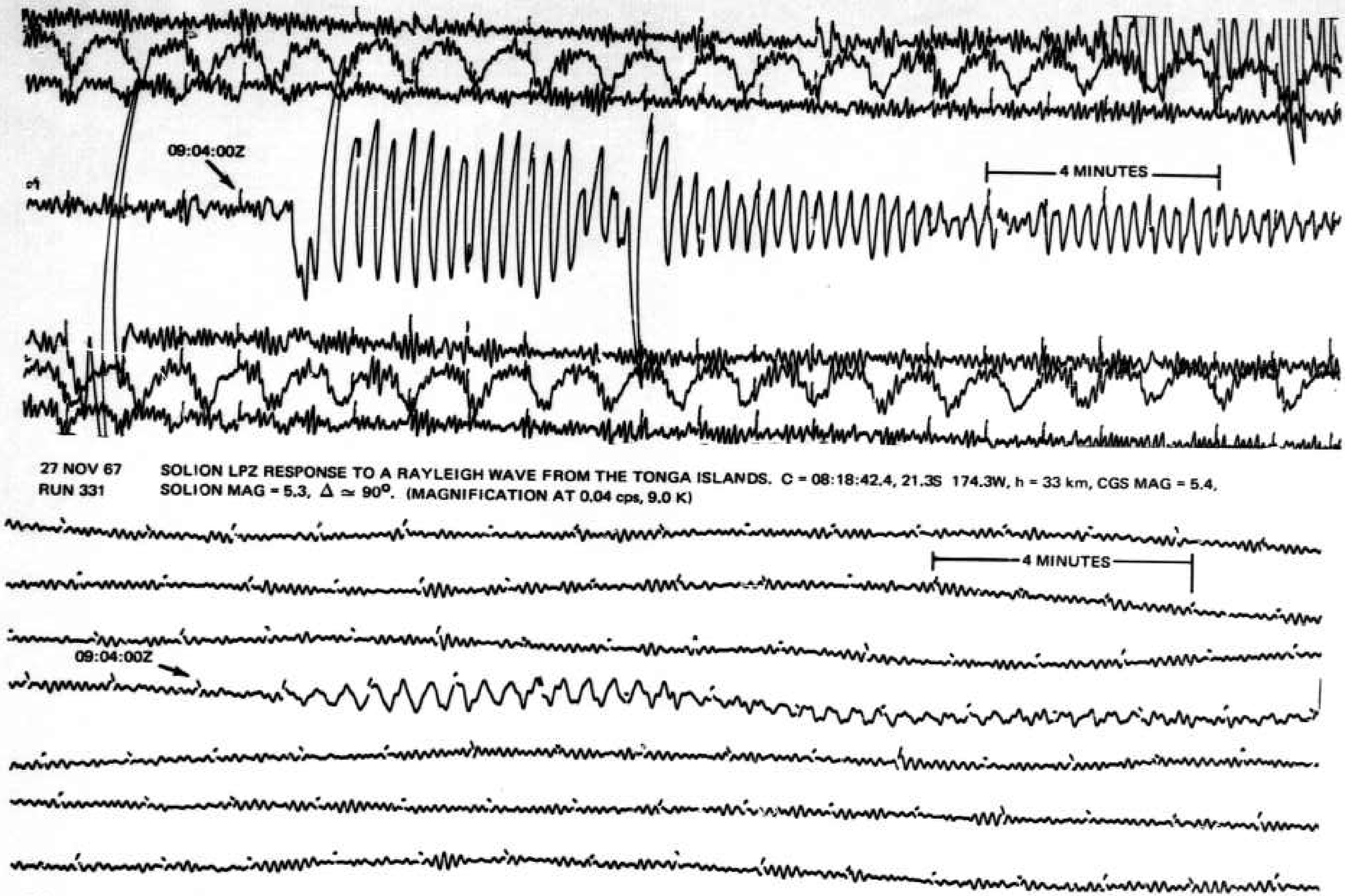
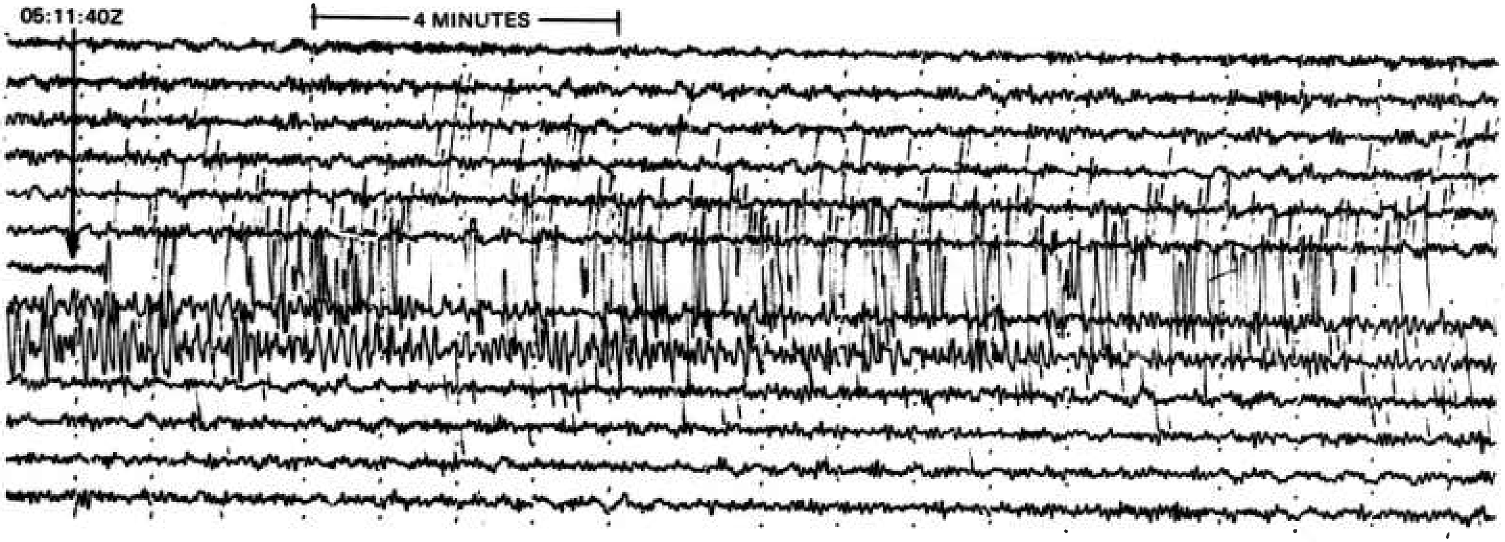


Figure 16. Solion long-period vertical seismogram showing a Rayleigh wave train from the Tonga Islands compared to a long-period vertical world-wide seismograph recording of the same Rayleigh wave train. (Magnification at 0.04 cps, 1.5K)



27 NOV 67 SOLION SPZ RESPONSE TO A COLORADO EARTHQUAKE O = 05:09:22.7, 40.0N 104.7W, h = 5 km, CGS MAG = 5.2, $\Delta \simeq 10^{o}$.
RUN 331 (MAGNIFICATION AT 1.0 cps, 70.5 K)

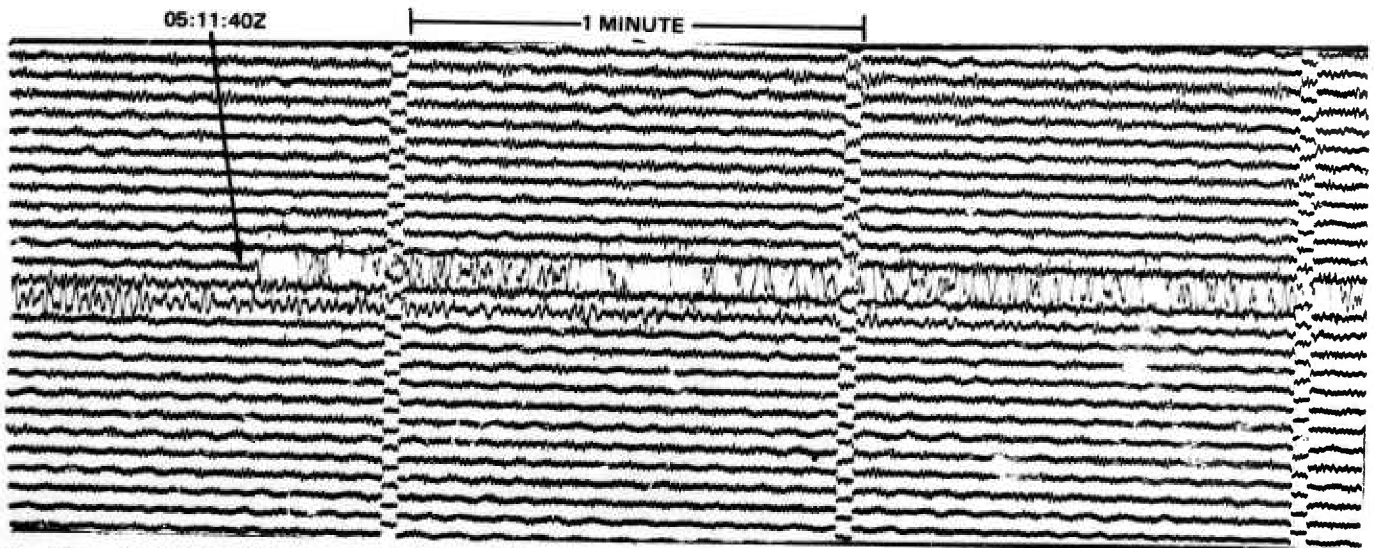


Figure 17. Solion short-period vertical seismogram showing a P-wave arrival from a Colorado earthquake compared to a short-period vertical world-wide seismograph recording of the same event (Magnification at 1.0 cps, 25K)

approximately proportional to the period of the change for periods greater than 20 seconds. Normal atmospheric pressure changes of up to 0.1 millibar as usually observed in that period range would not exceed the system noise level of 75 millimicrons. Because the response to pressure probably continues to be proportional to period out to very long periods and because larger atmospheric pressure changes are occasionally observed at periods of several minutes, noticeable response at longer periods may be expected on rare occasions. Apparent response of the vertical seismograph to microbarometric changes of 3 to 5 minutes period was observed on one occasion prior to sealing the vault.

Operation at Garland indicated that the solion long-period seismographs could be usefully operated at magnifications of 50K or more in a stable environment. We recommend, therefore, that the seismographs be installed and operated at TFSO for direct comparison with other long-period seismographs there. In addition, system noise tests indicated that the short-period response characteristic would be useful at magnifications of from two to three million, high enough to be compared with short-period seismographs at TFSO.

APPENDIX to TECHNICAL REPORT NO. 68-1

SOLION SEISMOMETER TEST PROGRAM

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1. INTRODUCTION

The solion long-period (LP) seismometer has a theoretical noise level that should make it suitable for use in high magnification LP seismographs. However, in practice, the instrument has exhibited noise levels too high to allow it to be used in high-magnification systems. The following proposed program has been planned to study the effects of environment on the seismometer with the hope that the noise level can be reduced by operating the seismometer in a controlled environment. Our experience with inertial pendulum-type seismometers has shown that environmental control is an extremely important factor when operating at high magnifications. Temperature and pressure changes acting on the seismometers have produced the most serious effects.

2. LABORATORY TEST PROCEDURES

2.1 INSTRUMENTATION AND INSTALLATION

Figure 1 is a block diagram of the instrumentation as it will be operated for this investigation. The seismometers will be installed in a tank vault in the environmental lab of Geotech at Garland, Texas. Each seismometer will be installed according to instructions for placement, as outlined on page 7 of Technical Memorandum CGS-1198-66-1, Operation and Maintenance Manual for the Solion Universal Seismometer (Robert S. Adair, May 1966). Each seismometer is covered with a styrofoam box and will be provided with insulation outside the box by filling all voids in the vault with fiberglass batting.

Heating units installed in the top of the vault will be used to stratify the air in the vault. After the installation is completed, 24 hours will be allowed for the vault temperature to stabilize. A thermistor bridge will be used to monitor the vault temperature and to verify that the vault temperature is sufficiently stable.

2.2 SEISMOGRAPH RESPONSE TO TEMPERATURE

2.2.1 Vertical Seismometer Response to Convection Currents

Figure 2 shows the proposed test setup for developing convection currents inside the insulated box provided with the solion seismometer. The test vault will not be sealed for this test.

To determine the effects of temperature changes on the seismometer, a low-frequency sinusoidal voltage will be applied to a resistive heating element near the top of the vault. Thermistor A (figure 2) will sense the temperature at the

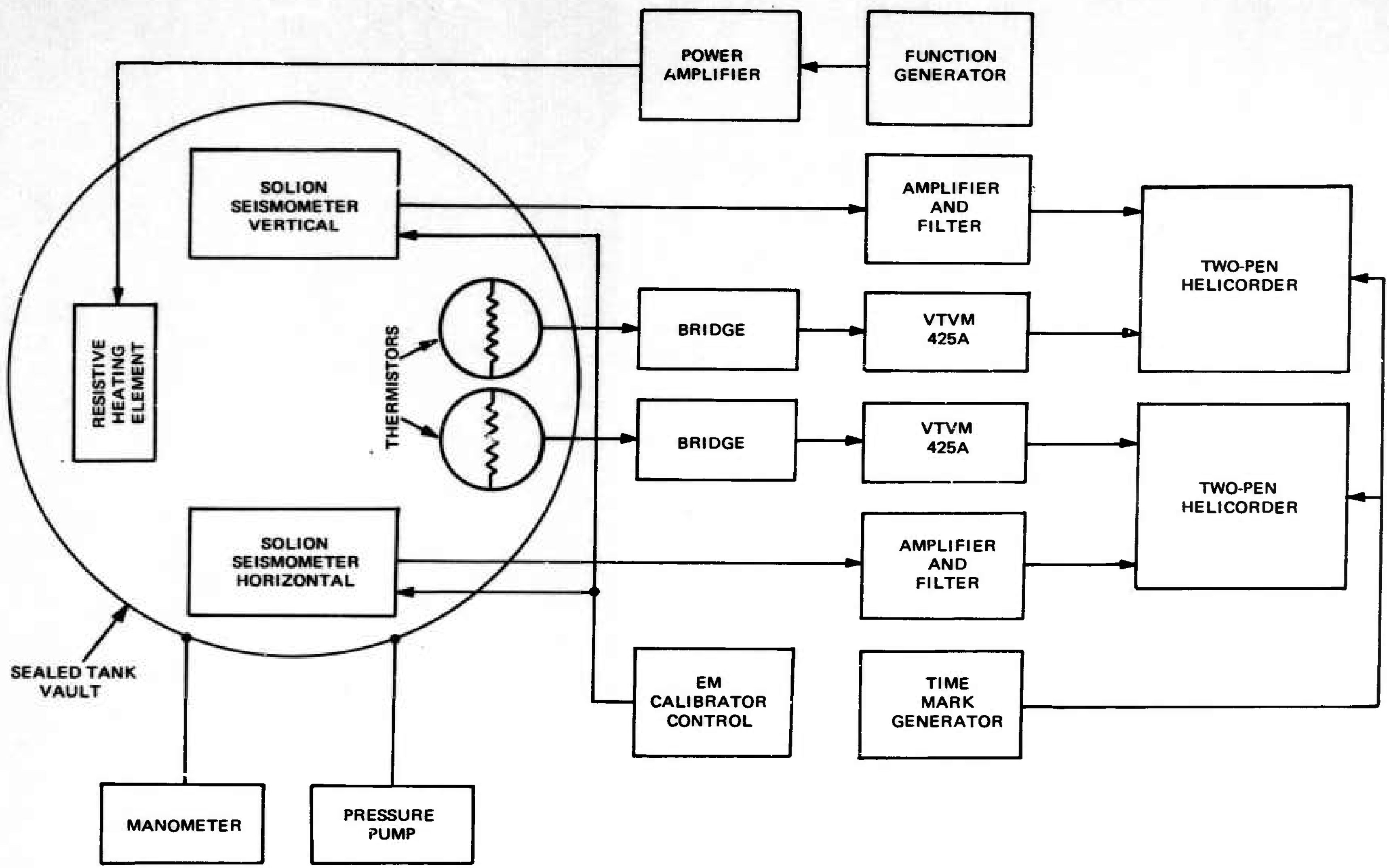

Figure 1. Block diagram for instrumentation for evaluation of solion seismometer

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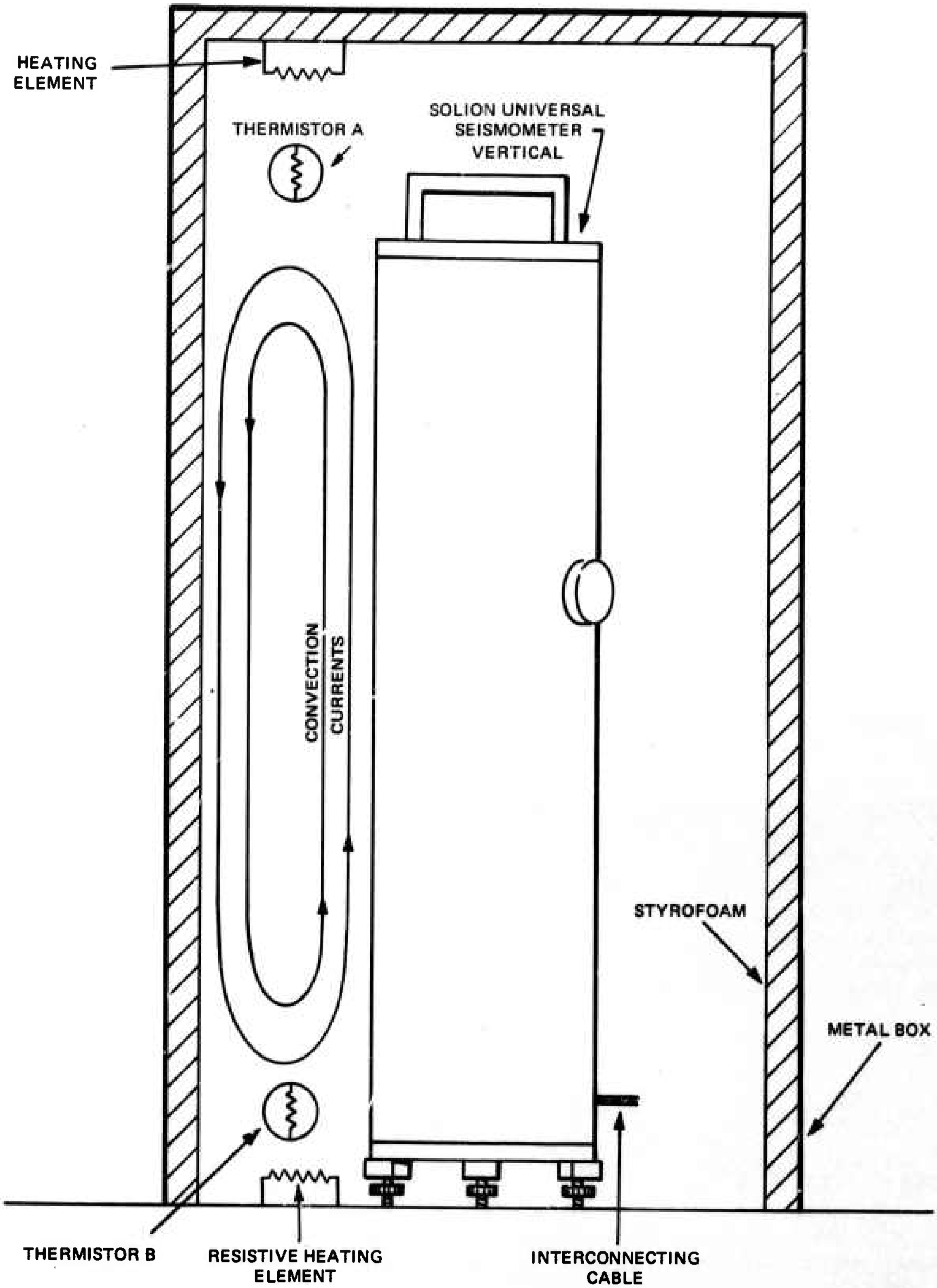

Figure 2. Test setup for generating convection currents

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top of the seismometer, and thermistor B will sense the temperature near the bottom. The peak voltage to the heating element will be increased until the seismograph output can be correlated with the temperature changes. The sensitivity of the seismometer to these temperature changes will be determined. The tests will be conducted during a calm day to minimize the effects of atmospheric pressure variations. Heat will then be applied near the bottom of the box to induce convection currents around the seismometer. The effects of these currents, as observed at the seismograph output, will be compared with the results of the previous test.

2.2.2 Seismometer Response to Ambient Temperature Changes

The ambient temperature in the tank vault will be increased in incremental steps and the vault temperature allowed to stabilize after each temperature change. Heat will be applied at the top of the vault to stratify the air column. Stabilization will be verified with a thermistor bridge. The tank vault will be sealed for this test with a pressure time constant of 8 hours (time required for pressure in the vault to leak off to 63 percent of its initial value). The pressure seal time constant will be verified by monitoring the pressure with an inclined manometer. The system noise level will be determined for each of the operating temperatures.

2.3 SEISMOGRAPH RESPONSE TO PRESSURE VARIATIONS

A sealed tank vault will be used to isolate the seismometers from atmospheric pressure variations. Before commencing the pressure test, 24 hours will be allowed for the vault temperature to stabilize. A thermistor bridge will be used to monitor the vault temperature and to verify that the temperature is sufficiently stable.

A pressure pump with a sinusoidal output will be operated at various frequencies within the pass band of the solion seismometer (0.0323 Hz to 0.0588 Hz). The pump displacement will be increased until the vault pressure changes correlate with the seismograph output. The pressure change (Δ P) will be monitored on a manometer. The sensitivity of the seismometer to pressure changes will be determined, and a frequency response of the seismograph to pressure variation will be plotted. The temperature changes, caused by compression and expansion of the air in the vault, will be recorded during the pressure tests, and the data will be compared with the data taken while varying the temperature under constant pressure. The results should provide an estimate of the effect of each of the two variables.

2.4 SEISMOGRAPH RESPONSE TO SOLION BIAS INSTABILITIES

Power supply fluctuations will be monitored by amplifying any fluctuations and recording them on a Helicorder for correlation with the seismograph output. Figure 3 illustrates the suggested test instrumentation.

Stray signal (60 Hz, ac hum) pickup will be minimized. Two-conductor shielded cable will be used between the seismometer and the amplifier load circuit. An oscilloscope will be used to monitor ac on the data lines.

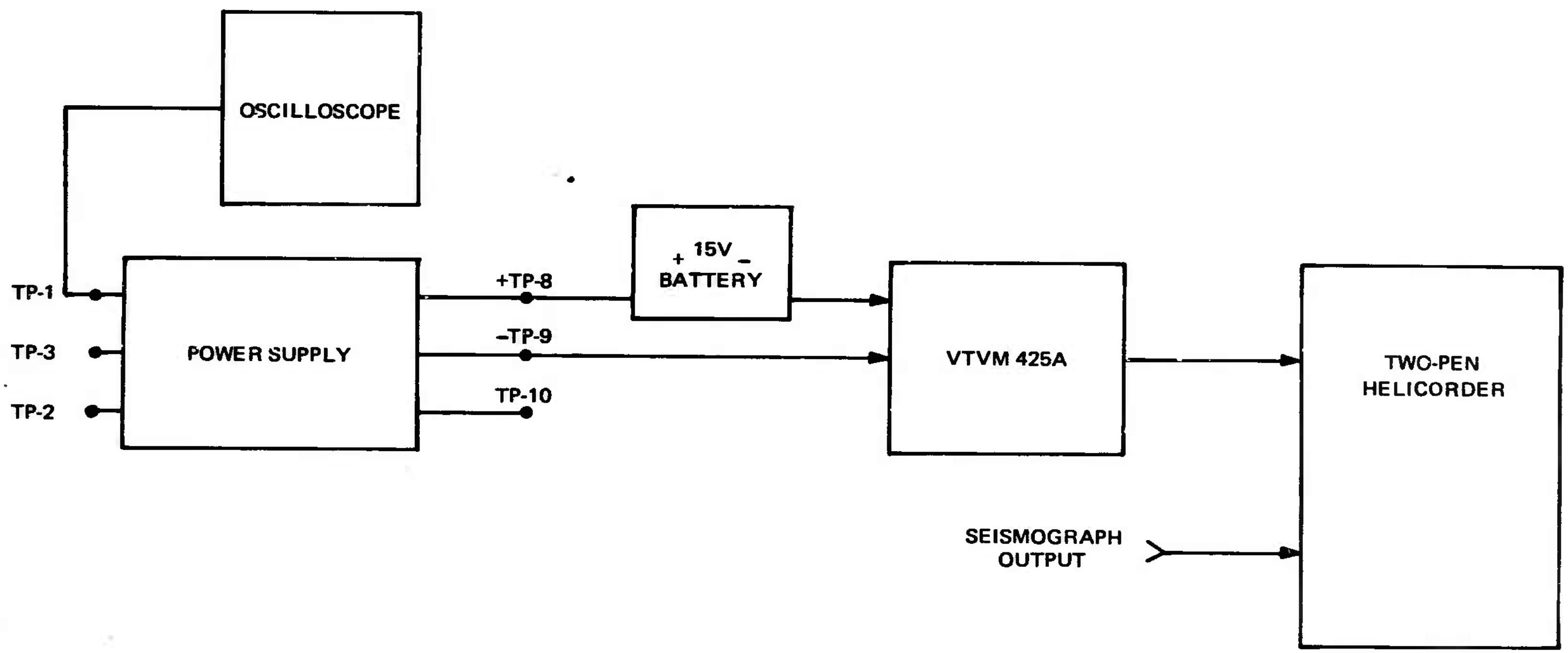

Figure 3. Block diagram of instrumentation for testing power supply fluctuations

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If seismometer environmental control (pressure and temperature) reduces system noise, various load circuits and amplifier configurations will be investigated to obtain the best dc bias stabilization.

3. OPERATIONS IN CONTROLLED ENVIRONMENT AT TFSO

If the laboratory tests conducted at Garland indicate that controlled environments and/or dc bias stabilization reduces the system noise significantly (approximately 12 dB is the minimum attenuation required), the system will be transported to TFSO and installed in the walk-in vault using the installation techniques developed during the laboratory tests. Data will be recorded on routine station LP recording facilities (Develocorder and magnetic tape) for best data correlation with the TFSO LP instrumentation. The system will be operated at TFSO for a minimum of 4 weeks.

4. REPORTS

Status reports will be submitted as part of the routine monthly report. A final report of the tests will be presented giving details of test procedures, test results, and recommendations. The report will be submitted within 30 days after completion of the tests.

5. SCHEDULE

We expect to complete the evaluation program on the solion seismographs approximately 4 months after receiving approval of the test plan, assuming that no extensive delay is encountered in receiving the solion units. The estimated shop-level cost of the manometer, thermistor bridges, and miscellaneous materials for the tests is $200. Approximately 2 man-months of effort will be required for the laboratory tests and 1 man-month of effort will be required for the field tests at TFSO.

Funds available under the Project VT/7702 (Contract AF 33657-67-C-0091) are adequate to support these tests.

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13. ABSTRACT

Environmental tests were performed on a set of solion seismographs with emphasis on determination of noise produced by voltage variations, temperature variations, and pressure change at the seismometers. The seismometers, developed and built by the Defense Research Laboratory of the University of Texas use solion pressure transducers and mercury inertial masses. A long-period and a short-period response characteristic is obtained from each single seismometer by means of separate sets of filters in each amplifier. (U) We concluded that useful short-period magnifications of more than 2 million and useful long-period magnifications of approximately 50 thousand could be obtained in a controlled field environment.

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Effects of power supply variations on solion seismograph						
Temperature effects						
Pressure variation effects						